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Solving the Traffic Problem by Using A Simulation Model

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Abstract

This paper presents a traffic light simulation model, which is composed of 6 submodels coded in Arena to help analyze the traffic problem. The model adopts average arrival time and average departure time to simulate the arrival and leaving number of cars on roads. In the experiment, each submodel represents a road that has 3 intersections. The simulation results show that different traffic light duration policies will cause different effects on traffic congestion. Therefore, we can use this model to obtain a good traffic light duration policy for solving the traffic problem.

Keywords

Simulation Model, Traffic Light Control System, and Traffic Congestion.

1. Introduction

Traffic congestion has been causing many critical problems and challenges in most cities of modern countries. To a commuter or traveller, congestion means lost time, missed opportunities, and frustration. To an employer, congestion means lost worker productivity, trade opportunities, delivery delays, and increased costs. To solve congestion problems is feasible not only by physically constructing new facilities and policies but also by building information technology transportation management systems. A growing body of evidence proves that simply expanding a road infrastructure cannot solve traffic congestion problems. In fact, building new roads can actually compound congestion, in some cases, by inducing greater demands for vehicle travel -- demands that quickly eat away the additional capacity. Therefore, many countries are working to manage their existing transportation systems to improve mobility, safety, and traffic flows in order to reduce the demand of vehicle use. By enhancing public transport, route guidance systems, traffic signal improvements, and incident management, congestion can be improved greatly. Of course, construction of new private bus way, expressways, or subway to increase these growth for easy travel has not kept pace. From recent analytical statistics (US department of transportation, 2007), it is estimated that roughly half of the congestion is what is known as recurring congestion - caused by recurring demands that exist virtually every day, where road use exceeds existing capacity. The other half is due to non-recurring congestion caused by temporary disruptions. Four main reasons of non-recurring congestion are: traffic incidents (ranging from disabled vehicles to major crashes), work zones, weather, and special events. Non-recurring events dramatically reduce available capacity and reliability of the entire transportation system. Therefore, researchers have done many researches to increase capacity and remove bottlenecks.

Wen and Yang (2006) developed a dynamic and automatic traffic light control system for solving the road congestion problem. They simulated a specific road, the Chung San North road in Taipei, Taiwan, to discuss whether a road simulation model can solve a congestion problem. Moreover, Schaefer et al. (1998) developed a simulation model for evaluating freeway lane control signing. The simulation results show that lane control has little influence on congestion. However, the region between heavy and medium traffic flow is sensitive to lane control. Chen and Yang (2000, 2003) have created an algorithm to find a minimum total time path to simulate the operations of traffic-light control in a city. Stoilova and Stoilov (1998) also built a simulation model to measure the best of traffic lights to achieve low noise levels with optimal traffic management and environmental pollution. Grau and Barcelo (1992) and Messmerand and Papageorgiou (1999) discussed the minimum of queue lengths in different intersections. Meanwhile, to aid traffic management systems, Nooralahiyan et al. (1997) adopted a Time Delay Neural Network (TDNN) to classify individual traveling vehicles based on their speed-independent acoustic signature. The TDNN network was trained and resulted in 94% accuracy for training patterns and 82.4% accuracy for test patterns. Besides, by adopting the shortest path algorithms, many other researches about solving traffic problems have been published (Chabini, 1997; Chabini, 1998; Ikeda, Hsu, & Imai, 1994; Ikeda & Imail, 1994; Liu, 1997; Xia & Shao, 2005). Wen and Hsu (2005) designed a route navigation system with a new revised shortest-path routing algorithm and made a comparison of performance evaluation. Our research focuses on traffic signal improvements to solve traffic congestion problem, which will be discussed below.

2. Definitions and notations of the simulation model

To illustrate how the system works, we have developed a 6-road traffic simulation model, which contains 9 intersections, by using Arena. Before giving example, let us introduce the definition of notations as follows:

Variables:

T: The time for passing a length of a car.

Nij: The remaining space of the j_{th} segment of i road, which is measured by the number of cars (In the model, the remaining space is set to 88.), where j=2,3 i=A, B, C, D, E, F.

cross i: The mean time between cars passing the stop line at the first intersection where i=A1, B1, C1, D1, E1, F1.

cross j: The mean time between cars passing the stop line at the second intersection j=A2, B2, C2, D2, E2, F2.

cross k: The mean time between cars passing the stop line at the third intersection k=A3, B3, C3, D3, E3, F3.

clock light i: Simulation clock time for traffic light signal at the first intersection turning to red where i=A1, B1, C1, D1, E1, F1.

Clock light j: Simulation clock time for traffic light signal at the second intersection turning to red where j=A2, B2, C2, D2, E2, F2.

clock cross i: Current simulation time of the car permitting to leave the stop line at the first intersection (TNOW) pluses **cross I** where i=A1, B1, C1, D1, E1, F1.

Clock cross j: Current simulation time of the car arriving at the stop line at the second intersection (TNOW) pluses **cross j** where j=A2, B2, C2, D2, E2, F2.

green i: Green light duration at the first intersection where i=A1, B1, C1, D1, E1, F1.

red i: Red light duration at the first intersection where i=A1, B1, C1, D1, E1, F1.

green j: Green light duration at the second intersection where j=A2, B2, C2, D2, E2, F2.

red j: Red light duration at the second intersection where j=A2, B2, C2, D2, E2, F2.

green k: Green light duration at the third intersection where k=A3, B3, C3, D3, E3, F3.

red k: Red light duration at the third intersection where k=A3, B3, C3, D3, E3, F3.

Resources:

switch i: A resource for controlling traffic light signal or for determining whether a car permits to pass the stop line at the first intersection where i=A1, B1, C1, D1, E1, F1.

switch j: A resource for controlling traffic light signal or for determining whether a car permits to pass the stop line at the second intersection where j=A2, B2, C2, D2, E2, F2.

switch k: A resource for controlling traffic light signal or for determining whether a car permits to pass the stop line at the third intersection where k=A3, B3, C3, D3, E3, F3.

Queues:

iQueue: A queue at the first intersection to store all waiting cars, which do not have rights to pass the intersection where i=A1, B1, C1, D1, E1, F1.

jQueue: A queue at the second intersection to store all waiting cars, which do not have rights to pass the intersection where j=A2, B2, C2, D2, E2, F2.

kQueue: A queue at the third intersection to store all waiting cars, which do not have rights to pass the intersection where k=A3, B3, C3, D3, E3, F3.

3 Description of the simulation model

The 6-road traffic control simulation model is composed of 6 submodels, A, B, C, D, E, and F, which simulate A, B, C, D, E, and F road's traffic conditions as shown in Fig. 1. Submodels A, B, and C are similar and Submodels D, E, and F are similar. Therefore, we only explain the processes of submodels A and D (see Fig. 2 and Fig. 3). The rest of submodels can be understood easily. In the model, we assume that the interarrival time for each car is 1.7 seconds, The mean time between cars passing the stop line at each intersection (i.e., **cross i, j,** and **k**) is 1.2 seconds, and the time for passing a length of a car (i.e., **T**) is 0.41 seconds, which are physically observed in average. We also suppose that the traffic light signals at every intersection on a road are set to the same duration and color. In Figure 2, there are four modules named **Light control A1, Light control A2, Light control A3,** and **Car arrival A.** The process in the upper dash area of Figure 2 controls the traffic signal at the first intersection on road A. **Light control A1** generates an entity to control traffic light signal. **Assign for light A1 clock time** gets the current simulation time. **Prempt** seizes the resource **switch A1** that has first priority to get the resource. **Delay for red light A1** sets the duration for red light. **Release switch A1** releases the resource **switch A1** for allowing cars to seize the resource. Finally, **Delay for green light A1** sets the duration for green light. Like the process of **Light control A1**, the processes of **Light control A2** and **Light control A3** are the same. So, it is easy to derive from the same processes.

The lower dash area of Fig. 2 shows the moving process of cars in the first segment of road A. **Car arrival A** generates each entity for representing a car based on the interarrival time. The block **Queue** presents the number or waiting time of cars in the queue, which cannot pass through the first intersection on road A. The block **Seize** catches the resource **switch A1** for getting the right to passing through the first intersection on road A. **Seize space of the second segment A road** takes the resource **spaceA2** to check whether the second segment on the A road has space or not. Then, **Assign for clock time passing intersection A1** uses an equation, **TNOW+ cross A1,** to represent the time for passing the first intersection on road A. **Delay for passing intersection A1** is the time for a car passing the stop line at the first intersection on road A. **Release switch A1 for next car** frees the resource **switch A1** for allowing the next car to move. **Assign for decreasing space A2** reduces by 1 to calculate the space in the second segment on road A. **Delay for driving through the second segment A road** uses an equation, **NA2*T,** to represent how long it will take to pass through the remaining space in the second segment on road A. Upon the traffic light at the first intersection changing to red, a car entity holding **switch A1** needs to release the resource **switch A1** (i.e., the **Preempt** block in the upper dash area in Fig. 2 takes one unit of a resource **switch A1** away from the **Seize** block in the lower dash area that originally seizes it). The interrupted car entity then will be sent to the **Delay** block (i.e., a dummy block whose value is 0). The purpose of the dummy block is to continue the process for going to **Decide clock light A1 Eqt clock cross A1**. Next, **Decide clock light A1 Eqt clock cross A1** examines if **clock light A1** is equal to **cross A1,** then delay the remaining time, which is 0, for passing the stop line at intersection A1, then go to **Assign for decreasing space A2**. If **clock light A1** is not equal to **cross A1**, then go to the module **Decide remaining time for passing intersection A1 Eqt 0.** If the remaining time for passing the stop line at intersection A1 is equal to 0, then the car entity will be added into the **Queue** block with the first priority by using the **Insert** block. Otherwise, the car entity will go to the **Delay** block on the right side of **Decide remaining time for passing intersection A1 Eqt 0** and delay the remaining time.

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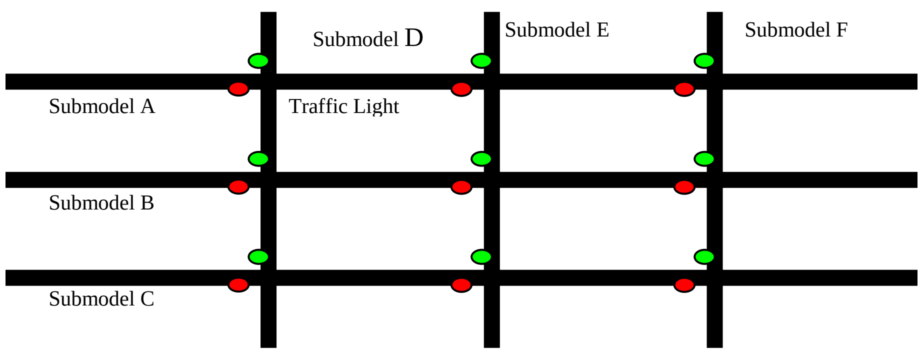

Figure 1: A Traffic Control Simulation.

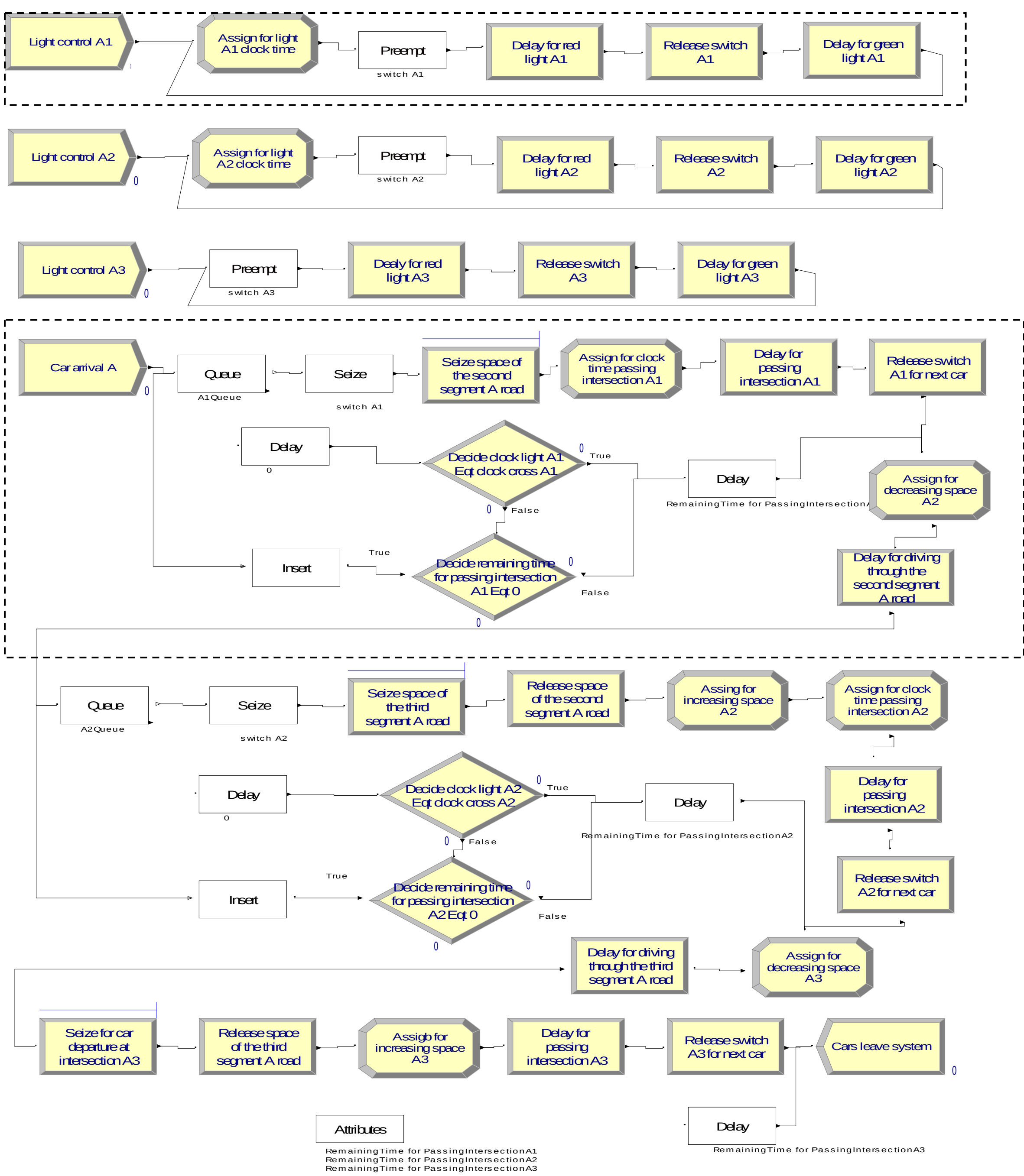

Figure 2: The Traffic Simulation Submodel A

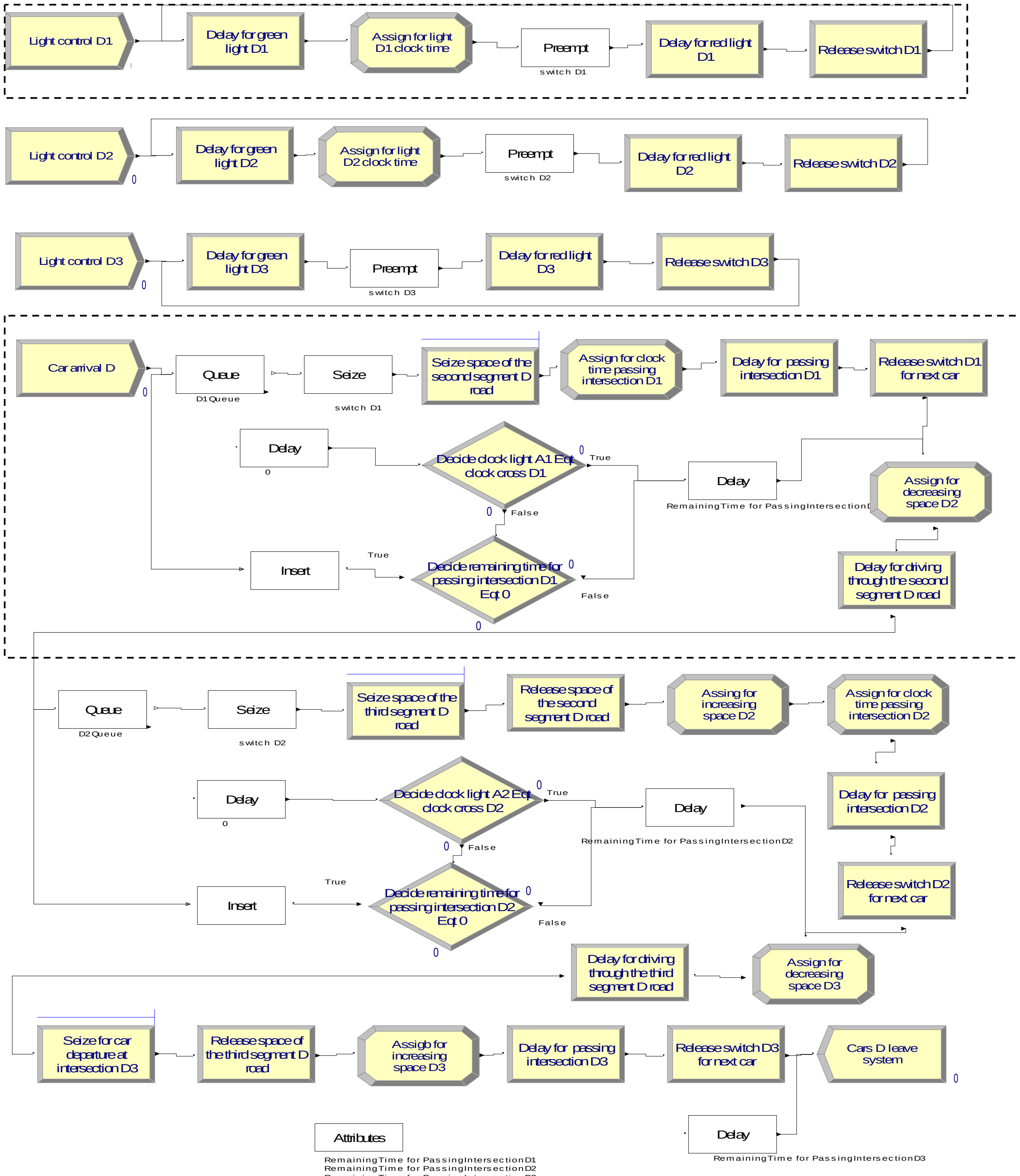

Figure 3: The Traffic Simulation Submodel D

4. Simulation results and discussions

As previously discussed, FTP utilizes the control connection to coordinate the data connection and execute commands on the File Systems of both the user and the server. FTP utilizes the Telnet protocol to execute the commands (Postel & Reynolds 1985). This fundamental design lends itself to security breaches that may permit eavesdropping of user ID's, passwords, file names, and other information passed through the control channel. It also may allow an active attacker to change settings and execute commands on the file system (Brown & Jaatun 1992). This fundamental security flaw was initially addressed when Borman (1993) proposed the passing of authentication information, and a mechanism to enable encryption of the data after successful authentication for the Telnet protocol. The result was that user passwords would not be sent in clear text, and the data stream would be encrypted utilizing any general authentication and encryption system. However, it should noted that the "Telnet authentication and encryption option does not provide for integrity protection only (without confidentiality), and does not address the protection of the data channel" (Horowitz & Lunt 1997).

The simulation result shows that the best policy is both the green light and red light durations set to 65 seconds, where the average waiting time is the lowest. For example, the average waiting time at the queue of the first intersection of the road A is 1685.33 seconds. Hence basing on this police, we further fix the green light duration to 65 seconds and each time increase the red light duration by 15 seconds from 50 to 125 seconds for the road A, B and C at each intersection (i.e., g=65,r=50; g=65,r=65; g=65,r=80; g=65,r=95; g=65,r=110; and g=65,r=125 seconds). Also, we fix the red light duration to 65 seconds and each time increase the green light duration by 15 seconds from 50 to 125 seconds (i.e., g=50,r=65; g=65,r=65; g=80,r=65; g=95,r=65; g=110,r=65 and g=125,r=65 seconds). The simulation results are shown in Fig. 4 and Fig. 5. In Fig. 4 and Fig. 5, **nQueue** represent the queue at the first, second and third intersection of the road A, B and C respectively, where **n**=A1, A2, A3, B1, B2, B3, C1, C2 and C3. For example, B3Queue represents the queue at the third intersection of the road B. From Fig. 4 and Fig. 5 we know that the best light duration policy for the road A, B and C is the red light duration with 65 seconds and the green light duration with 125 seconds (i.e., the red light duration is 125 seconds and the green light duration is 65 seconds for the road D, E and F). At this policy, the average waiting time for instance at the queue of the first intersection of the road A (i.e., A1Queue) is 387.33 seconds.

It is worth to note that the best to the worst light duration policies in Fig. 5 are r65g125, r65g110, r65g95, r65g80, r65g65, and r65g50 respectively; in Fig. 4, they are r50g65, r65g65, r80g65, r95g65, r110g65, and r125g65 respectively. It seems to imply that the larger the green light duration is, the smaller the average waiting time is; the larger the red light duration is, the larger the average waiting time is. However, it should be reminded if the traffic light signals on roads A, B, and C in the East-West direction are green and those of roads D, E, and F in the North-South direction should be red. When the green light duration for East-West direction is set longer, in contrast, the red light duration of North-South direction will be longer as well. That means the advantage of longer green light duration at roads A, B, and C will be offset by the disadvantage of longer red light duration at roads D, E, and F. Therefore, which road adopts longer green light duration policy must depend on whether its traffic flow is heavy or not.

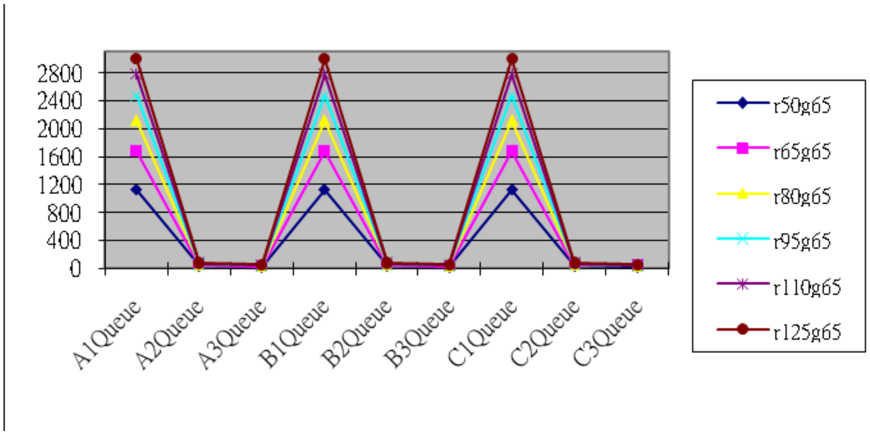

Figure 4: The Average Waiting Time for Different Red Light Durations and Same Green Light Durations (A,B,C)

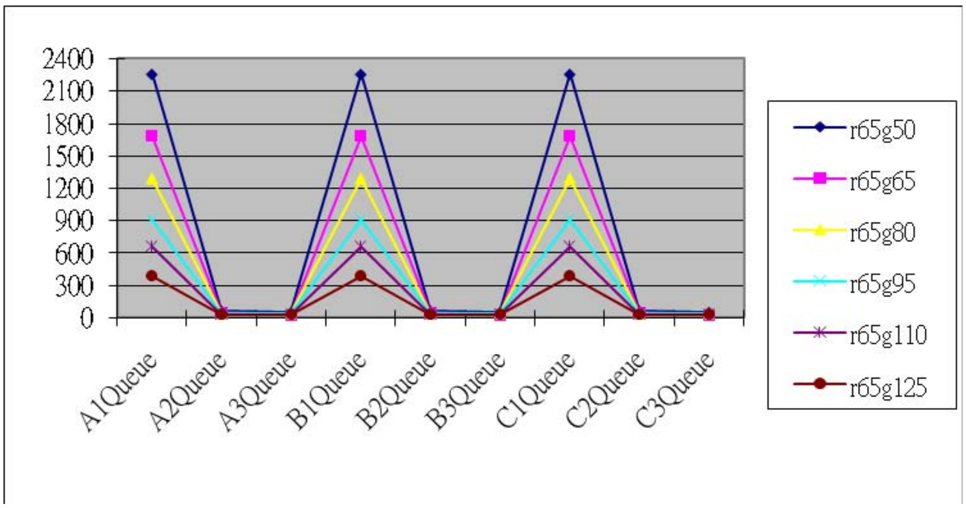

Figure 5: The Average Waiting Times for the Same Red Light Durations and Different Green Light Durations (A,B,C)

5. Conclusions and future work

This paper proposes a simulation model for improving traffic problem in rush hours. In order to analyze system performance, we design a traffic simulation model, which consists of 6 submodels. Each submodel represents a road which has 3 intersections. The simulation results show that the light duration policies will affect the performance in light of the average waiting time. A longer green light duration policy can eliminate the pressure of traffic congestion. However, it could cause another direction roads traffic jam. A good combination between green light and red light durations is contingent on each road's traffic condition. Basically, a road got heavy traffic flow might adopt longer green light duration policy. On the contrary, a road got light traffic flow might adopt longer red light duration policy.

Although this paper presents and analyzes different traffic light duration policies to see the influences on waiting time, there are still several aspects where we can further improve its functions. In particular, we can extend the simulation model to use two-way roads or allow cars turning left or right to let the model more close to the reality. In addition, because we can collect traffic flow and average car speed by using RFID technology, the method of dynamically finding a best route or a second optimal route for road navigation systems will be also a major research issue in the future.

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